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METHODS OF REDUCING FITTING WORK DURING CONSTRUCTION OF A SHIP --ETC(U)
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WASHINGTON, D.C. 20390

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TITLE: 6 Methods of Reducing Fitting Work During Construction of a Ship Hull in the Building Berth

(Puti Umen'sheniya Prigonochnykh Rabot Pri Postroyke Korpusa Sudna Na Stapele)

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PAGES: 14 21 Trans. of

SOURCE: Sudostroyeniye, [redacted] N4 1975
Pages 51-54

1975.

(USSR)

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RECEIVED
OCT 25 1977
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ORIGINAL LANGUAGE: Russian

TRANSLATOR: C

14 NISC-TRANS[redacted] 3956

APPROVED P.T.K.

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SUDOSTROYENIYE, No. 4, 1975, pp. 51-54

METHODS OF REDUCING FITTING WORK DURING CONSTRUCTION OF A SHIP HULL IN THE BUILDING BERTH*

by L. Ts. Adlershteyn

One of the main trends toward improvement in construction of ship hulls in the building berth is reduction of the volume of manual operations, and in particular -- of fitting work. First of all, it is necessary to define what is included in the scope of fitting work. Accuracy of the hull structure (assembly, section, or block) depends on the technology of its fabricating processes and precision of the hull's component parts. This refers to the structure as a whole (dimensions and form of the entire hull), as well as its individual members (shape of joint edges, positioning of the framing). Accuracy requirements in fabrication of the hull structure are in turn determined by the accuracy requirements of building the ship hull in the building berth. Thus, if the accuracy of structure fabrication is not sufficient to satisfy the accuracy requirements of the assembly work in the building berth as to form and dimensions of the ship hull, the need for fitting work in the building berth is obvious.

Fitting work includes operations for bringing the forms and dimensions of individual hull structures delivered for assembling in the building berth to conform to the design and technological requirements of precision for the entire ship hull and

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* Full translation of the original article.

its structural members. These operations are: setting up hull structures for scribing the assemblage dimensional allowances, the actual scribing and removal of dimensional allowances, matching root opening of the plates and framing, bringing the plate and framing edges to the fairing lines, aligning joint edges in one plane, tightening of the plate to the framing at the field connections, and other similar operations. Straightening of the hull structures may also be included with these, since it is also due to the necessity of bringing the structure forms to conform to the technical specifications.

All of this work can be divided into three groups: matching the edges of the panels and framing; straightening and alignment of the edges; adjustment of the panels and framing. A diagram of fitting work in the building berth is shown in Fig. 1.

Of primary importance also is determination of the required labor input and duration of the fitting work. Today its main bulk is performed by the shipwrights. It may even be said that the greatest portion of the time and labor of [redacted] plate erection is spent on fitting operations. Fitting operations take up all of the shipwrights' time, and, to a much lesser degree, that of checkers, welders, power-press operators, and oxygen-cutting operators. The following are not considered to be fitting operations: erection of sections, assemblies, and miscellaneous component parts of the structure, as well as butt joining of field connections. The portion of shearing and oxygen-cutting operations connected with trimming of the root of a joint and correction of

welding defects, or with removal of the assembly jigs, are also not a part of the fitting operations.

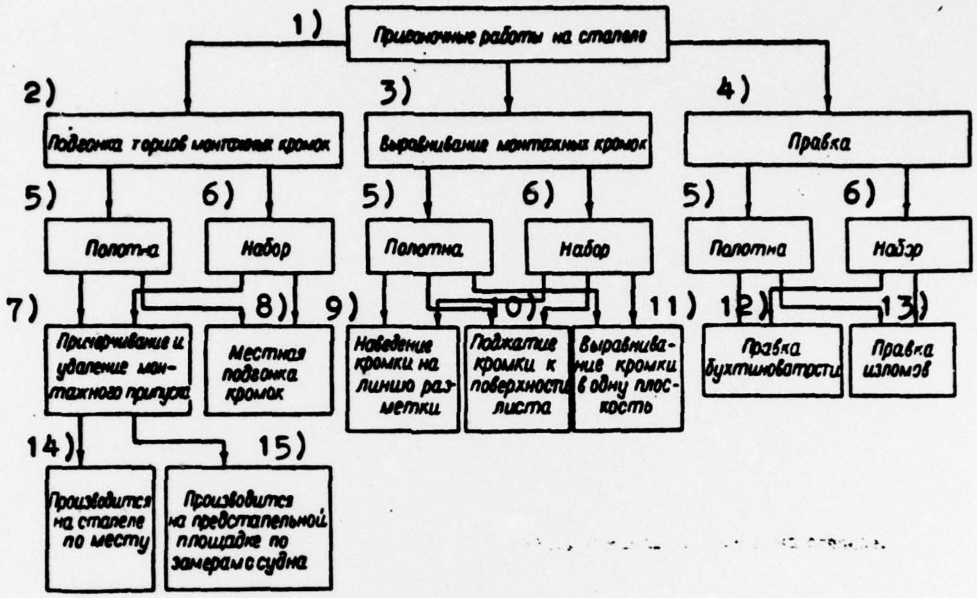

Fig. 1. Diagram of fitting work in the building berth. Key: 1 -- Fitting work in the building berth; 2 -- Fitting of the ends of joint edges; 3 -- Alignment of joint edges; 4 -- Straightening; 5 -- Panel; 6 -- Framing; 7 -- Scribing and removal of the dimensional allowances; 8 -- Local adjustment of edges; 9 -- Bringing the edges to the layout line; 10 -- Tightening of the edge to the plate surface; 11 -- Levelling of the edge to the same plane; 12 -- Trueing the edges; 13 -- Strengthening the cleavages; 14 -- Performed in situ in the building berth; 15 -- Performed in the area in front of the building berth from the measurements taken at ship side.

Today, there is hardly any statistical, accepted standard, or design information on the labor-intensiveness of fitting operations in the building berth. In particular, the existing time norms of assembly in the building berth are determined on the basis of the geometric parameters of the sections and field connections (overall dimensions of a section, plate thickness, framing shapes), without considering the extent of technological displacements leading to fitting operations (misalignment of the planes of the structural members being butt joined together, deviations from the fairing lines, and so forth). For this reason, Table 1 adduces the results of a tentative expert estimate of such labor-intensiveness. It is apparent from the Table that today up to 40% of all hull work in the building berth consists of fitting operations.

The relatively large volume of fitting operations involving manual, mostly heavy, labor, renders their drastic reduction a very urgent problem. This problem can be solved in two ways: by improving the technology of fitting operation processes, mainly through mechanization, which ensures increased labor productivity, and by a decrease in deviations from the (design) forms and dimensions of the hull structures, since such deviations create a need for fitting work in the building berth.

Analysis of the efforts of shipbuilding plants towards increasing the accuracy of hull work, as well as of standard materials and investigations, demonstrates the importance of increasing the accuracy of fabrication and erection of hull structures in order to appreciably reduce the volume of fitting operations in

the building berth. At this point, at least two problems are present: The advisability of an increase (or, in the general case, of variation) of the accuracy; and the possibility of an increase (variation) of the accuracy.

Table 1

Volume of fitting work during construction of a ship hull in the building berth

1) Вид работ	8) Удельное значение вида работ по отношению ко всем корпусным работам на стапеле, %	9) Часть трудоемкости вида работ, затрачиваемой на пригонку, %	10) Удельное значение пригоночных работ по отношению ко всем корпусным работам на стапеле, %
2) Сборочные работы	40	70	28,0
3) Сварка	30	2	0,6
4) Проверочные работы	5	20	1,0
5) Рубка и зачистка	6	50	3,0
6) Тепловая резка, строжка и правка	8	80	6,4
7) Прочие работы	11	0	0
	100		39,0

Key: 1 -- Type of work; 2 -- Erection work; 3 -- Welding; 4 -- Checking operations; 5 -- Shearing and cleaning; 6 -- Thermal cutting, gas gouging, and straightening; 7 -- Other operations; 8 -- Specific share of the type of work in relation to all hull work in the building berth, %; 9 -- Labor-intensive portion of the work used for fitting operations, %; 10 -- Specific share of fitting operations in relation to all hull work in the building berth, %.

The problem of advisability of increase in accuracy presupposes first of all the knowledge of how this can affect the technical and economic plan, i.e., the part that reduces the volume of fitting operations. For this it is necessary to know the dependence of the magnitude of labor-intensiveness of the hull work on the error values in the forms and dimensions of hull structures, and on the value of technological displacements of the field connections prior to their assembly. So far, these dependences have not yet been determined. As stated above, the standard task time units accepted in the field for performance of hull work in the building berth depend on the nominal (design and mold loft) geometrical dimensions of the structures, but not on the extent of the production process displacements prior to assembly.

Not knowing the quantitative influence on the labor input required not only of the extent of the displacements, but of many other structural and technological factors also (operating procedures in performance of individual fabrication methods, working conditions, tools and equipment used, and so forth), one cannot determine by calculation the dependence of labor input on the errors in the form and dimensions of the hull structures. However, there is still a way of statistical investigation of the dependences between labor input and magnitude of technological displacements prior to [redacted] assembly. Such dependences, of course, must be correlating dependences, due to the presence of many random factors.

The second problem -- possibility of an increase (or of

variation in general) of the accuracy of geometric parameters of the hull structures -- presupposes, first of all, a knowledge of the causes leading to the production process displacements and errors in the form and dimensions of the structures. With a knowledge of these causes and by action upon them, the accuracy may be varied.

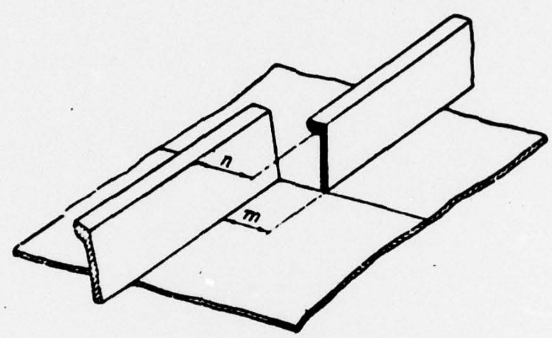

Fig. 2. Diagram of the measurements of production process displacements of bulb angle field joints.

Let us demonstrate by way of an example the possibility of establishing the dependence of labor input on the extent of production process displacements by measuring the time it takes to butt together identical structural members at various displacement values, but with all other conditions being equal*. Measurements

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* The work was carried out by V. A. Shatilov, Engineer.

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were taken during construction of a PYATIDESYATILETIYE SSSR class vessel, while butt joining the panel and longitudinal framing of

the outer plating and inner-bottom plating. Displacement values were measured with the aid of a steel meter of an accuracy up to 1 mm, and the time of butt joining was measured by stopwatch. The values of displacement of the framing and time of its butt joining were measured after completion of the butt joining of the panel. Displacement was determined at the toe m and at the flange n of each pair of the bulb angle (Fig. 2). Because the plates were already butt joined together, there was practically no upright displacement of the framing. The duration of butt joining was recorded from the instant when the workman was determining the size of the framing displacement until the conclusion of the last operation -- tack and spacer strip welding procedures. In all cases, butt joining of the framing was done using a 10 ton manually operated hydraulic jack.

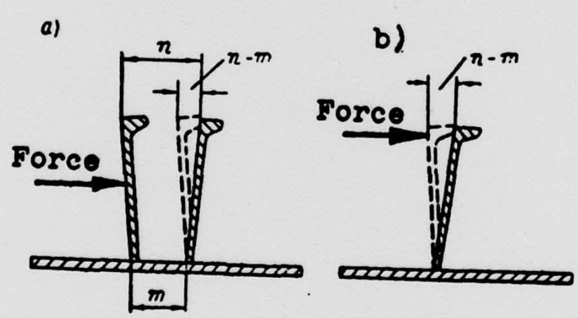

Fig. 3. Diagram of correction of production process displacements for the framing with $m < n$: a -- at the outer plating; b -- at the head of the framing.

For the general case, butt joining of the framing consisted of the following operations: determination by the shipwright of the size and nature of framing displacement; removal of tack welds from the not-yet-welded portions of the framing using a flame torch; placement of a hydraulic jack at the base or at the mid height of the framing; correction of the displacement at the base of the framing; tack welding of the framing to the panel; placement of the hydraulic jack at the framing head; correction of displacement at the framing head; installation of spacer strips along the framing head. In every specific case, in order to correct the displacement of the framing, all or only a portion of all of the above enumerated operations had to be performed.

The calculated value of framing displacement is the total displacement at the point of application of the working force, and is determined depending on the correlation between m and n and the method of butt joining. For example, when $m < n$, displacement m is corrected using a hydraulic jack (Fig. 3,a), and the toe of the bulb angle is tack welded to the panel. At the

Table 2

Calculated value of framing displacement

1) Характеристика смещения	2) Расчетная величина смещения l
$m = n$	$l = m = n$
$m < n$	$l = m + (n - m) = n$
$m > n$	$l = m + (m - n) = 2m - n$
3) m и n разных знаков	$l = m + (m + n) = 2m + n$

Key: 1 -- Displacement characteristic; 2 -- Calculated value of the displacement l; 3 -- m and n are of different signs.

time when displacement at the base of the framing is being corrected, there takes place a reduction of the displacement at the head of the framing also by the [redacted] value of m. The remaining portion of the displacement at the head n - m (Fig. 3,b) is corrected with the aid of a hydraulic jack set either at the same place or moved nearer to the head of the bulb angle framing. Thus, for this case, the total value of the displacement which is corrected with the aid of a hydraulic jack is

$$\ell = m + (n - m) = n$$

Calculated displacement values for all cases possible in actual practice of the correlation between m and n values, determined in an analogous manner, are shown in Table 2. Fig. 4 shows the results of measurements of framing displacement values (with the subsequent determination of calculated displacement value ℓ) and labor input required for its butt joining in the building berth for No. 20 and 22 bulb angles.

In order to establish the relation between the calculated value of the framing displacement and the labor input required for its butt joining, the coefficients of correlation between these values, and then also the equations of the relation (by methodology*) shown in Table 3, were derived. Since in both cases

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* Guiding technical material 44-62 "Metodika statisticheskoy obrabotki empiricheskikh dannykh (Methods for Statistical Processing of Empirical Data)". Publishing House of Standards, 1966.

$r/m_r > 5$, it may be considered that between the calculated displacement of the framing and the time it takes to butt join it, there is a correlation dependence for which an equation of relation may be derived. The dependence thus obtained is shown in Fig. 4.

Table 3

Definition of the equations of relation

1) Тип набора	2) Коэффициент корреляции между t и l	3) Объем совокупности n	4) Ошибка коэффициента корреляции $m_r = \frac{1-r^2}{\sqrt{n}}$	$\frac{r}{m_r}$	5) Уравнение связи между t в чел-мин и l в мм
6) Полособульб № 20	0,560	43	0,104	5,4	$t = 0{,}452l + 8{,}68$
7) Полособульб № 22	0,704	55	0,068	10,4	$t = 0{,}814l + 6{,}00$

Key: 1 -- Framing type; 2 -- Coefficient of correlation between t and ℓ; 3 -- Totality volume of n; 4 -- Coefficient of correlation error; 5 -- Equation of the relation between t in man/min and ℓ in mm; 6 -- No. 20 bulb angle; No. 22 bulb angle.

Displacement of field joint edges of a panel of the sections being butt joined together was measured over sections of the joint 2000 mm long. Butt joining was done with the use of a spacer strip and wedge. Using a 2000 mm length as a base, the labor input required for correction of the displacement and the average displacement were determined. The time required for butt joining the panel is a total of the time taken by the performance of the

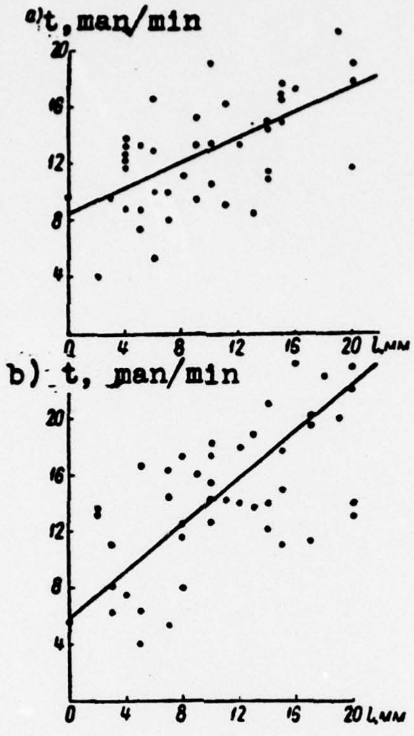

Fig. 4. Dependence of labor input required for butt joining the framing t on the calculated displacement value l : a -- framing fabricated of No. 20 bulb angle; b -- framing fabricated of No. 22 bulb angle.

following operations: installation and welding of field spacer strips, correction of the displacement with the aid of a wedge; spot arc welding of section edges; removal of assembly devices.

By way of an example, Fig. 5 shows the results of measurements of displacement values of a 12 mm thick panel and of the labor input required for its butt joining in the building berth. The equations of relation were derived in order to establish the

relation between the panel displacement value and the labor input required for its butt joining.

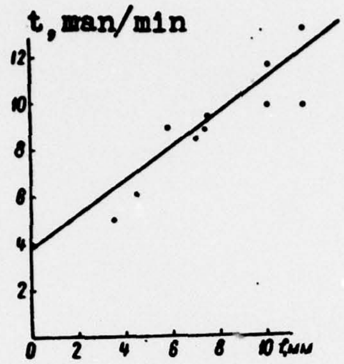

Fig. 5. Dependence of labor input required for butt joining of panel t on the displacement value ℓ (panel is 12 mm thick).

Although, undoubtedly, not comprehensive, the above examples, nevertheless, attest conclusively to a possibility in principle of establishing dependences between the technological displacement values in field connections of the hull and the labor input required for their correction; and to the advisability and effectiveness of reducing the volume of the fitting work due to decrease in technological displacements while in the building berth. The latter can be achieved only by increasing the accuracy of production of the sections and their assembly in the building berth.

CONCLUSIONS.

1. Today labor input in fitting operations constitutes 40% of the total labor input required for the construction of a ship

hull in the building berth. Therefore, reduction of the volume of fitting operations is one of the most important objectives of improvement in hull construction.

2. Reduction of the volume of fitting operations should be achieved by:

-- perfecting the technology of their execution (for example, mechanization of correcting technological displacements and dimensional allowances, perfection of the methods of straightening of hull structures);

-- reduction in deviations in the form and dimensions of hull structures in the building berth, which in turn should be based on improvement of the design factors (rational division into sections, well-thought-out design of field connections, and so forth), as well as technological factors (raising the accuracy of fabrication of hull sections, expanding the area of application of preliminary contouring of the sections and blocks, more precise positioning of the sections in the building berth, and so forth).